XCEL:
eXtreme fast charge Cell Evaluation of Lithium-ion batteries
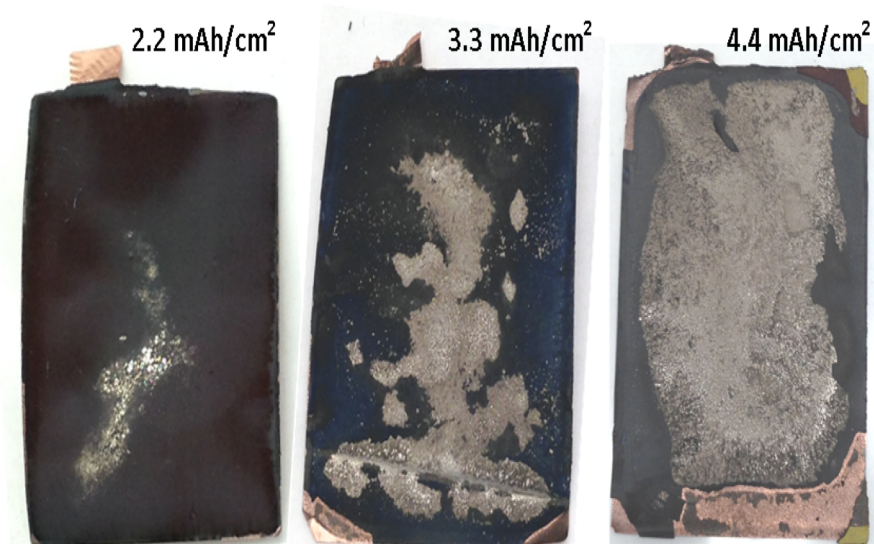
Project ID: Bat338

Presented by

Samm Gillard and Venkat Srinivasan

Overview

Timeline

- Project start date: October 2017
- Project end date: September 2019
- Percent complete: 33%

Barriers

- Slow charging of Li-ion batteries
- Li plating during fast charge
- Low energy density and high cost of fast-charge cells

Budget

- $3.8M over 2 years

Partners

- Argonne National Lab
- Idaho National Lab
- National Renewable Energy Lab
- Princeton U.

Relevance: DOE Summary of Fast Charge. Goal: 15 mins (350-400 kW)

- Combination of fast charge batteries and a network of high capacity chargers can minimize range anxiety and promote the market penetration of BEVs and increase total electric miles driven.

- **FY 2017 Study**
  - Assess the knowledge base of the fast charging capability of automotive batteries
  - Identify technical gaps for fast charging
  - Identify R&D opportunities

- **Issues Identified regarding Fast Charging**
  - Higher cost cells: (2X) compared to today's lithium-ion cells.
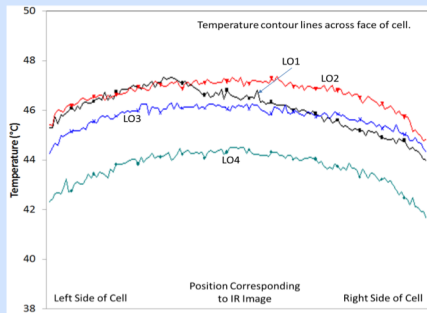 - Cycle Life & Durability of Cells
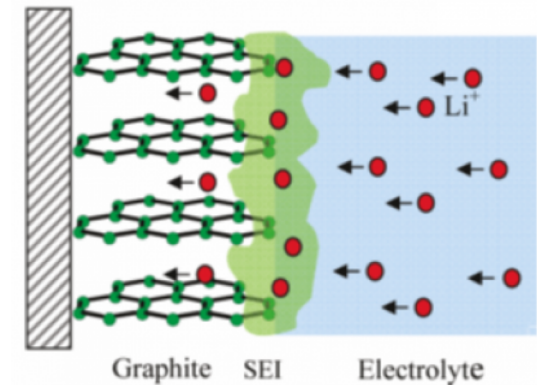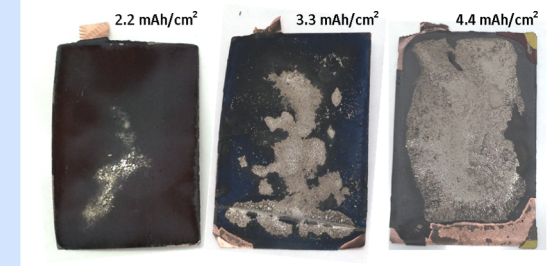

Plated lithium due to fast-charging
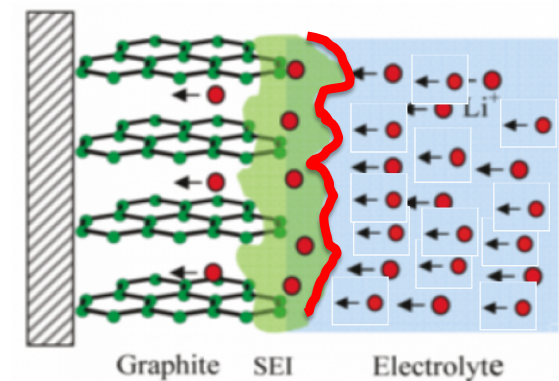
What Limits Fast Charge?
Based on the May 2017 Gap Assessment Report.
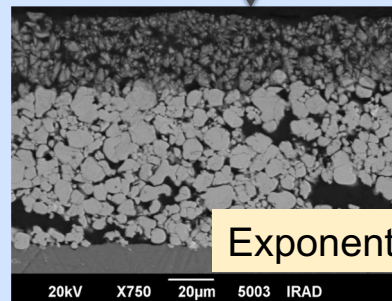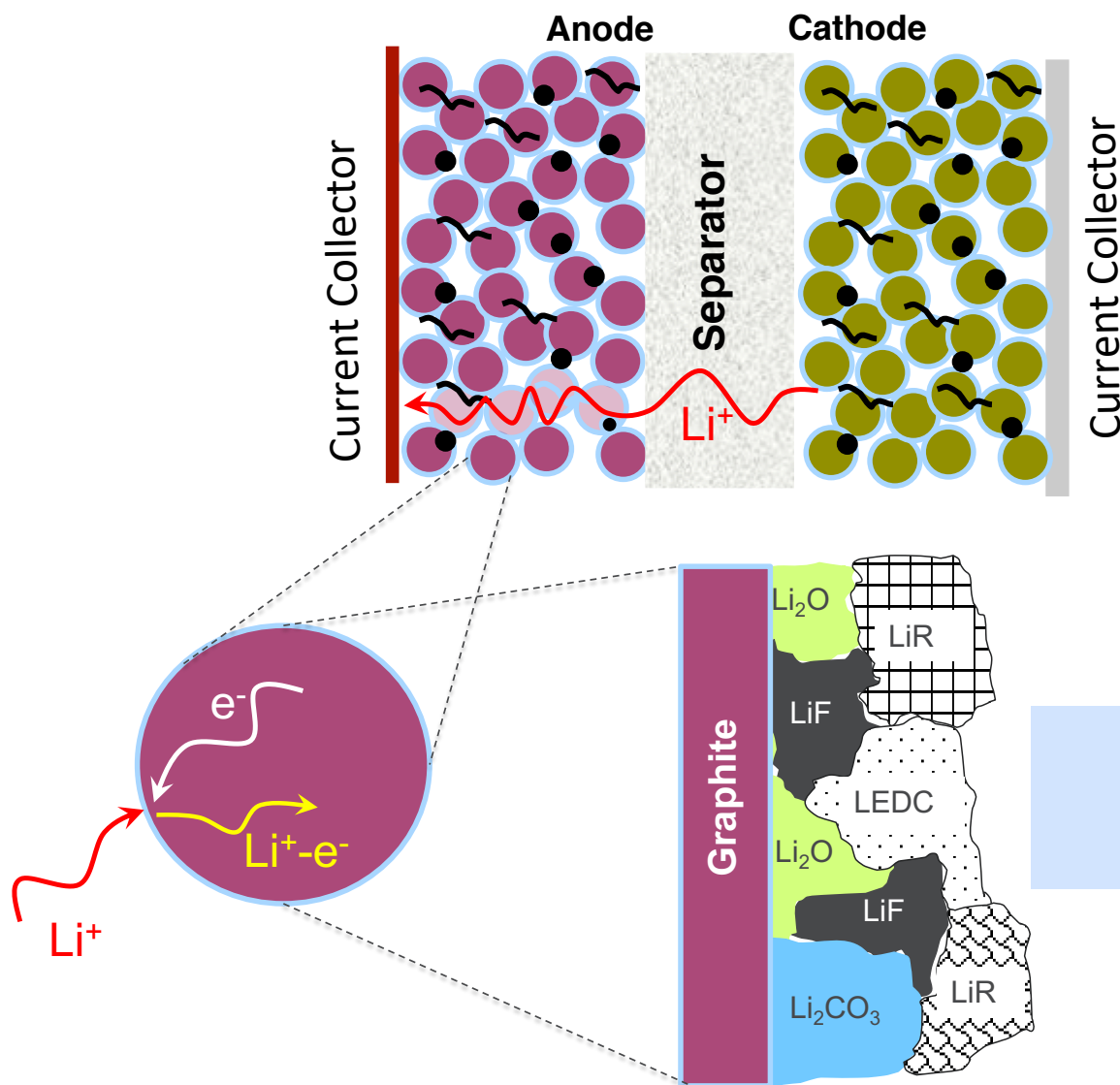

Temperature increase

Lithium plating

Limitation during fast charge

Particle breakup

Plating: A Number of Processes to Account For

Where is the bottleneck?

# Goal at the End of Year 1: Focus on Li plating
Scoping study that will allow targeted focus in outgoing years

1. Is the bottleneck in the anode bulk, the interface, or in the electrolyte?

2. Does the type of carbon matter for Li plating?

3. How high a loading can we sustain when charging at high rates?

4. Can we detect Li plating? How far can we push this?

Focus is on graphitic cells

NREL
NATIONAL RENEWABLE ENERGY LABORATORY
INL
Idaho National Laboratory
Argonne
NATIONAL LABORATORY

Approach: Combine experimental data with continuum-scale models

Leverage the strengths among the partner institutions
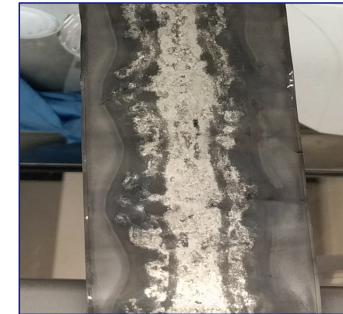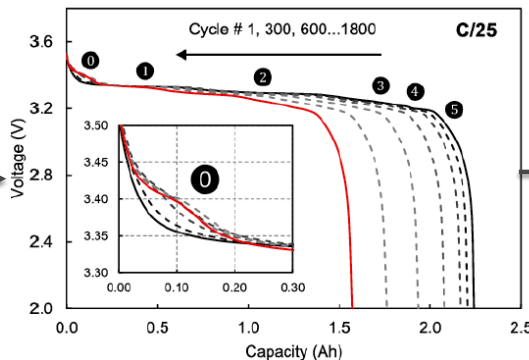
Cell Analysis, Modeling, and Prototyping (CAMP) facility

- Different graphite's
- Thin cells
- Cells with and without reference electrode

Argonne NATIONAL LABORATORY

Fast charge testing and electrochemical diagnostics

- Different charge rates.
- Short vs. long term cycling
- Coulombic efficiency
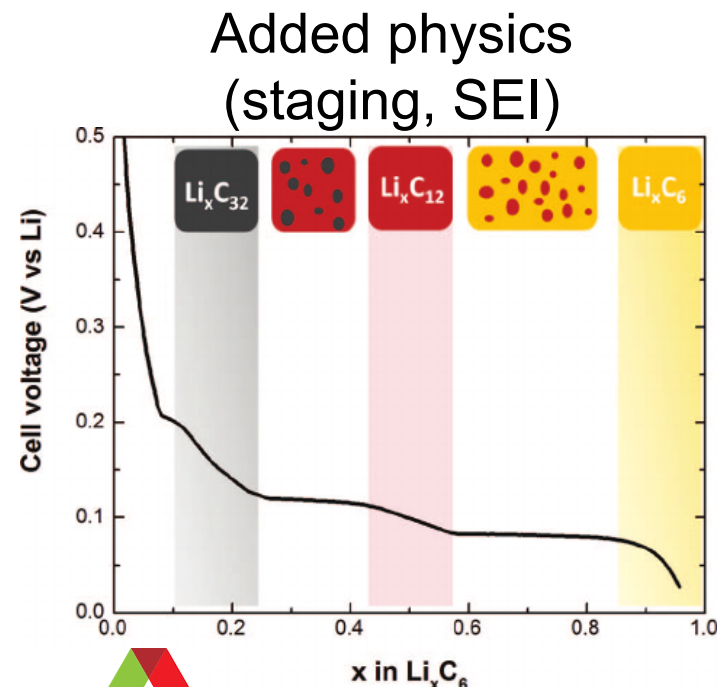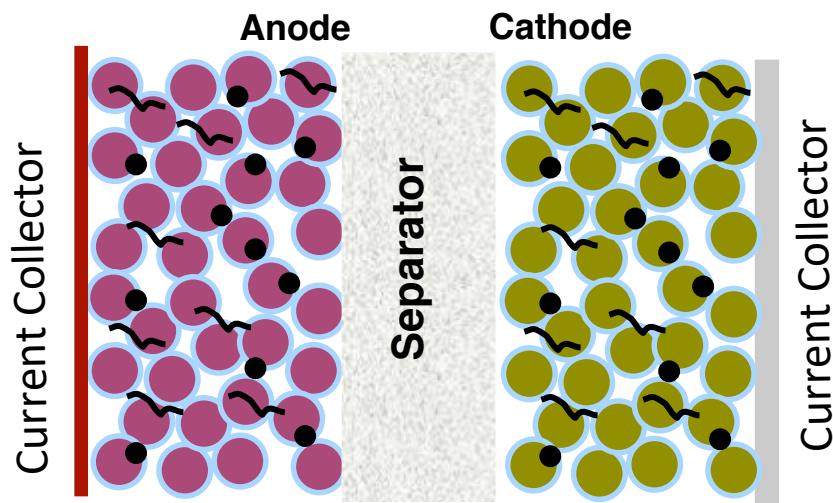- Electrochemical signatures of plating

Argonne NATIONAL LABORATORY   *iNL*

Post test tear-down diagnostics

- Li detection: SEM, XPS.
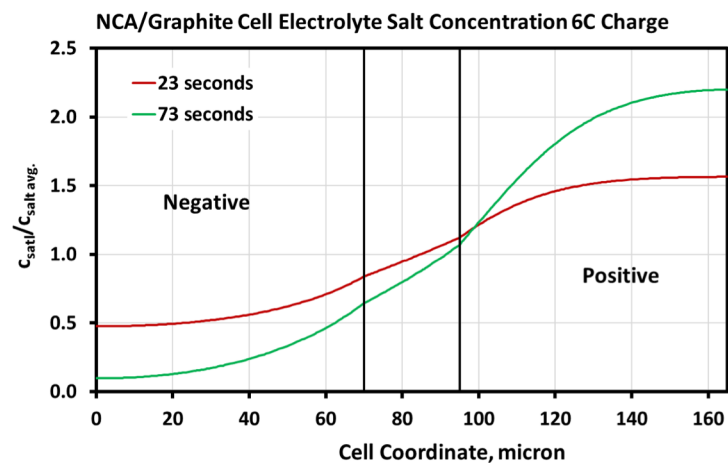- SEI detection: Raman, FTIR, XPS, HPLC
- Particle cracking: XRD, SEM

Argonne NATIONAL LABORATORY

The information from testing and post-test will feed into continuum models

Continuum Modeling to Identify Limitations

Anode **Cathode**
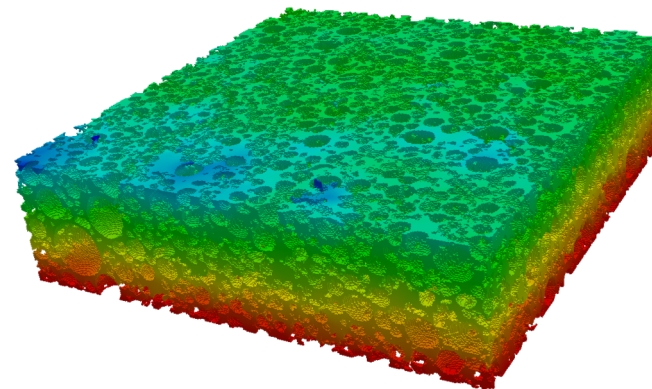
Current Collector

Separator

Current Collector

Added physics
(staging, SEI)

Macro Model

Microstructure Model

NCA/Graphite Cell Electrolyte Salt Concentration 6C Charge
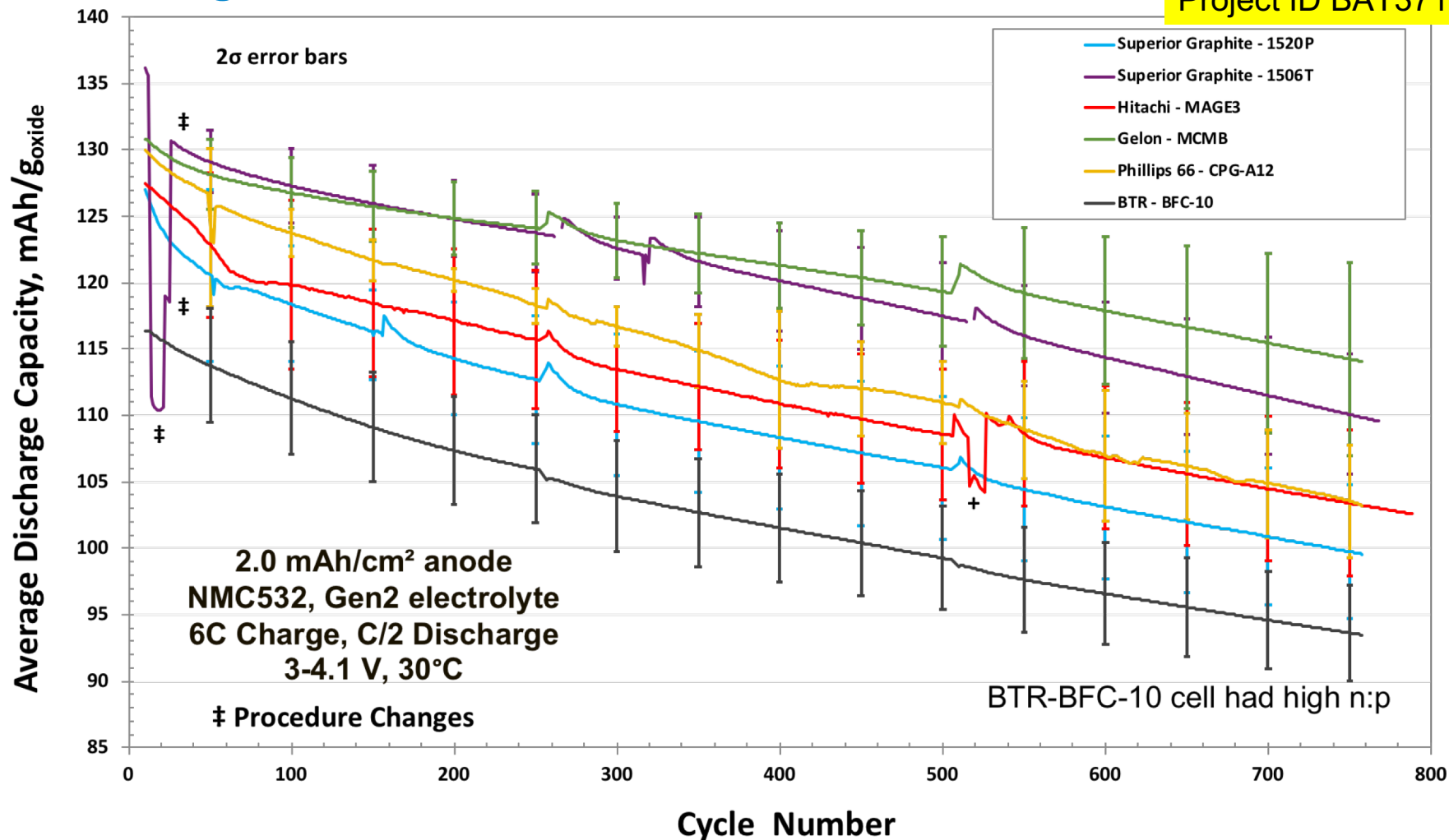- 23 seconds
- 73 seconds

Negative

Positive

Cell Coordinate, micron

What have we Learnt in the Last 8 months?
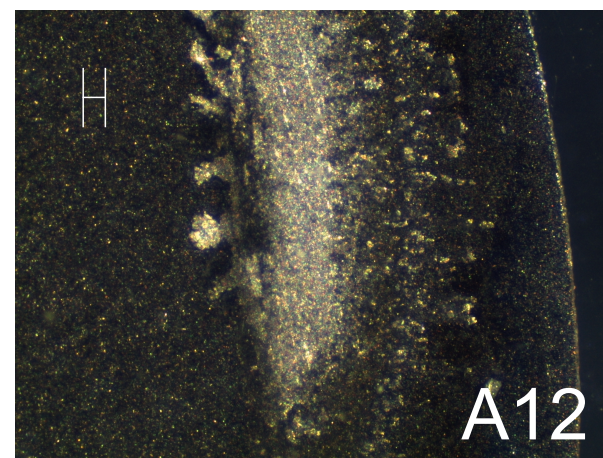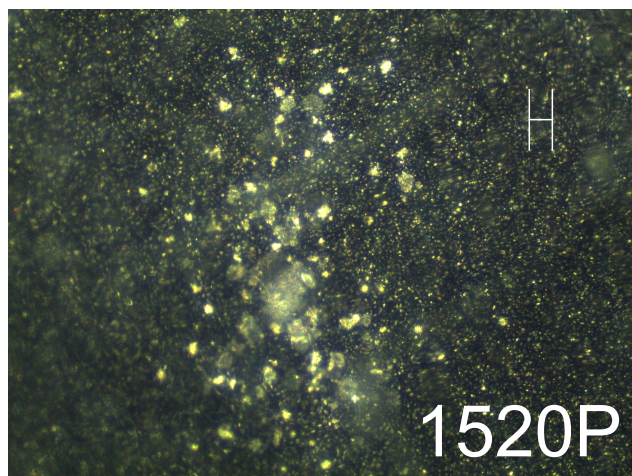
6 C charge on 2 mAh/cm² anode cells

Andy Jansen
Project ID BAT371

Thin cells cycle well. And fade seems similar with different graphite's and on CMC-SBR and PVDF binder cells

But it Appears that There is Still Some Plating
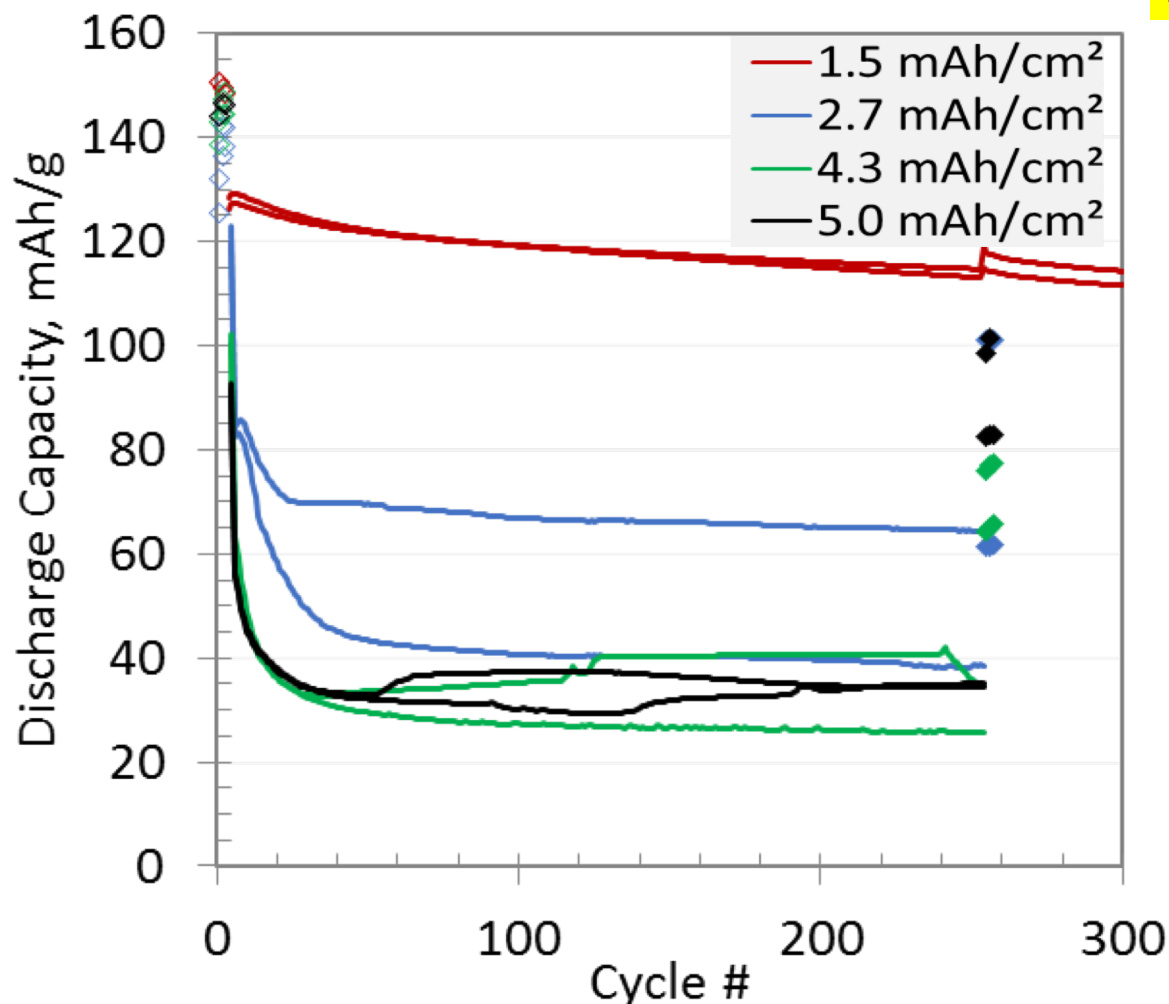
Ira Bloom
Project ID # BAT341

1520P

A12

	D:G area ratio
MAG E	1.00
MAG E3	1.08
MCMB	1.35
SLA1506	2.01
SLC1506T	1.89
A12	1.30
BTR	1.04
1520P	2.78

While only some graphite's (and only PvDF binders) show evidence of plating, does not mean others don't have Li deposits

What happens When we Increase the Loading?

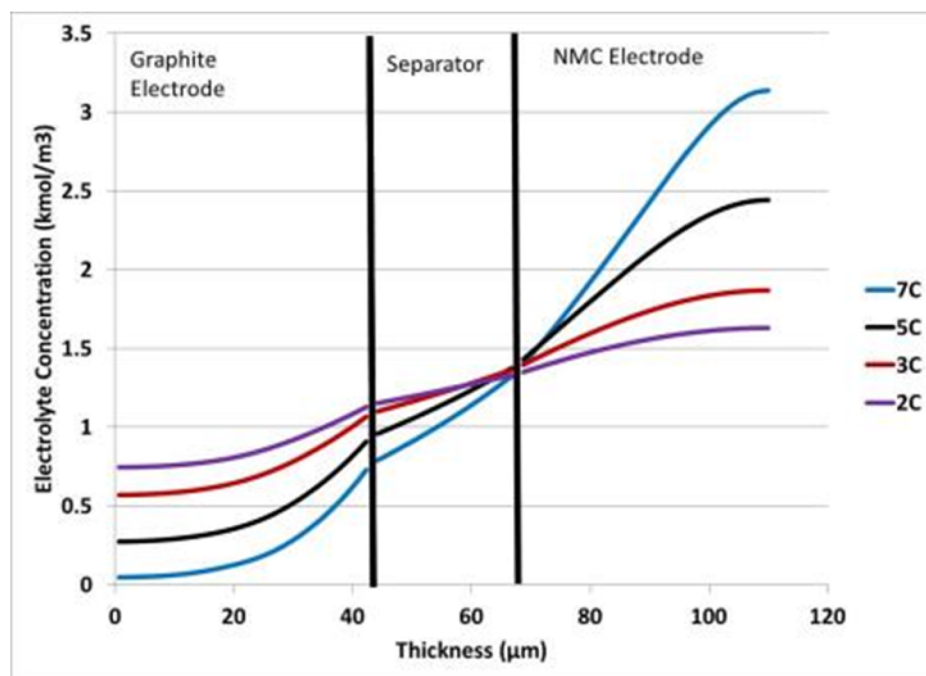**Conoco Philips GCP-A12**

Andy Jansen
Project ID BAT371

Results suggest the need to examine the reaction distribution in the porous anode
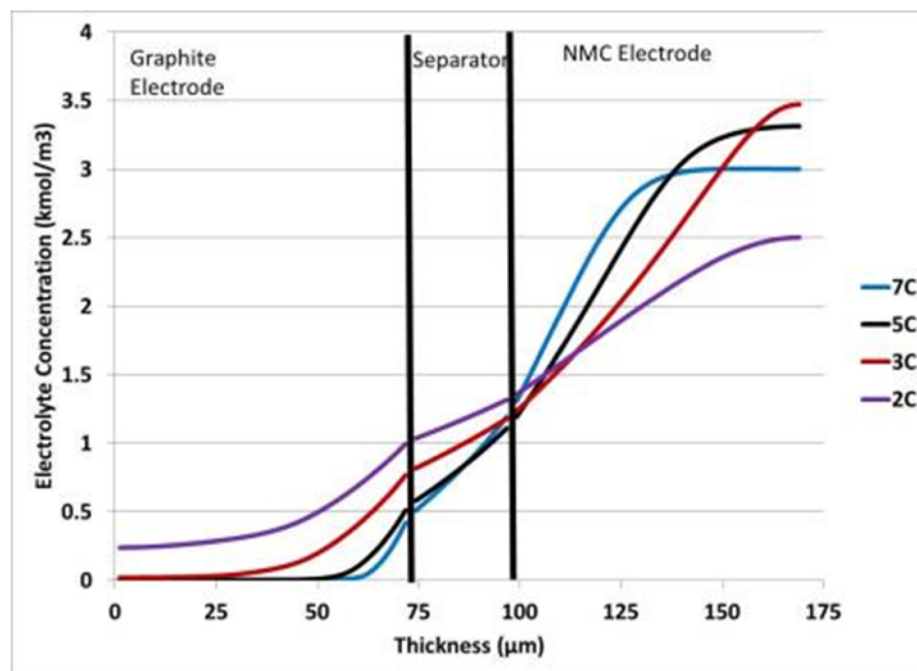
Model Provides Insights into Observations

Low Electrode Loading
1.5 mAh/cm² cathode (42 µm)
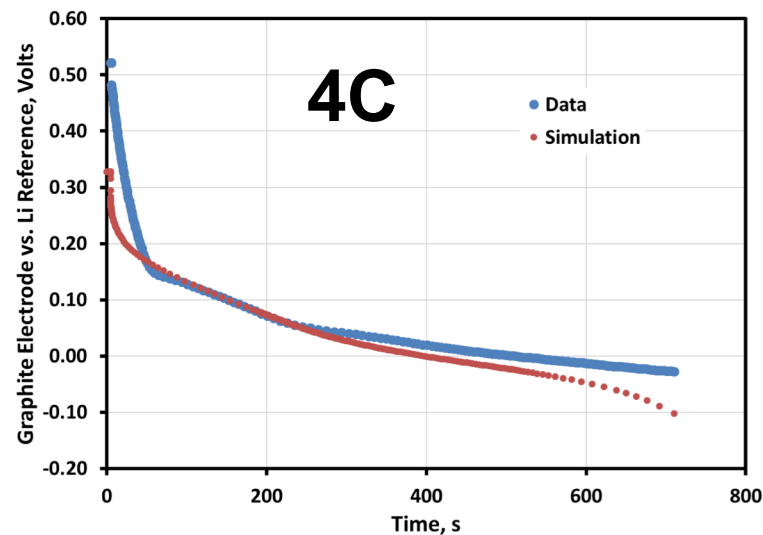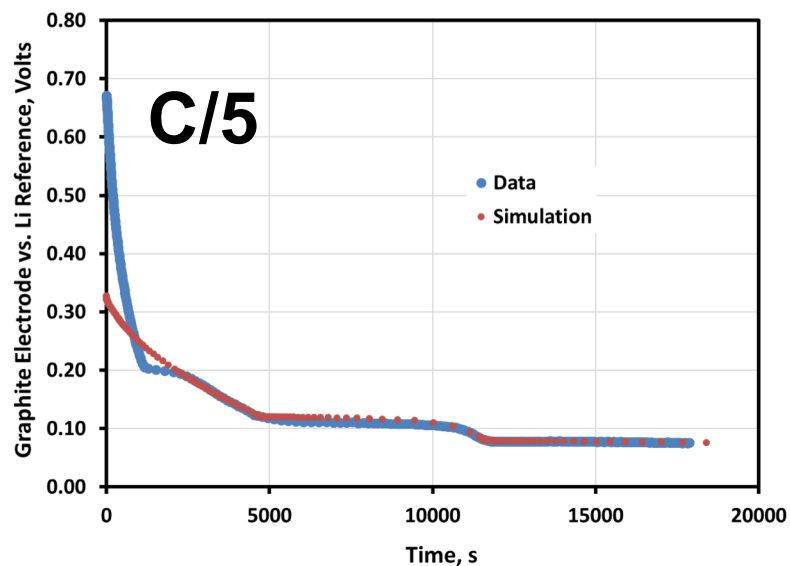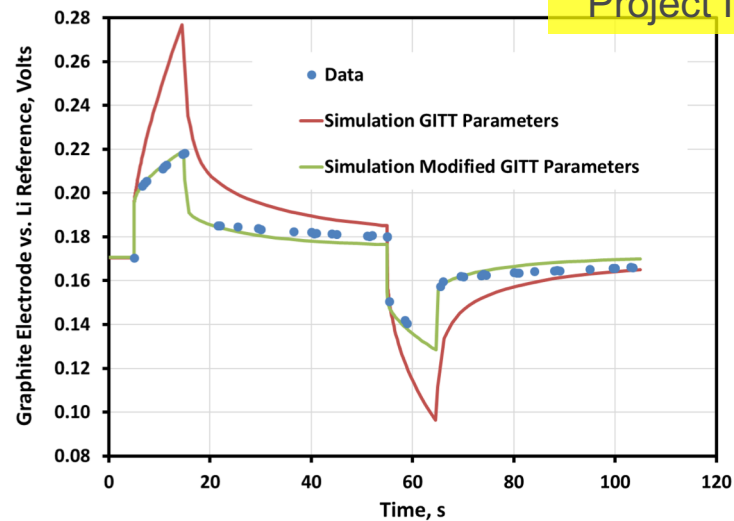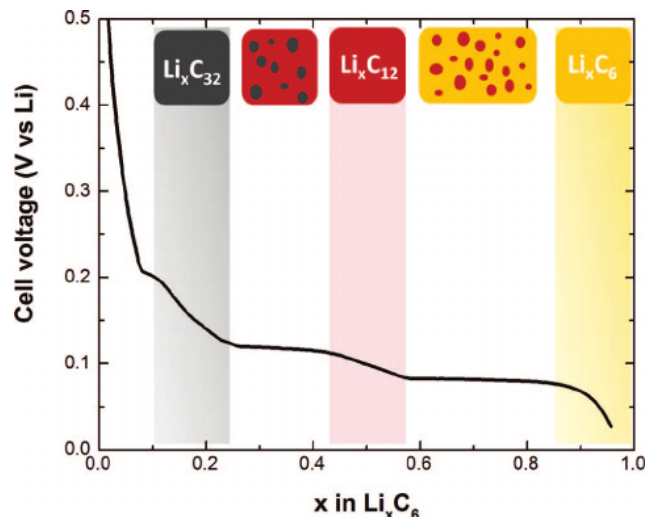1.84 mAh/cm² anode (43 µm)

Medium Electrode Loading
2.5 mAh/cm² cathode (71 µm)
3.07 mAh/cm² anode (87 µm)

Models already providing understanding
But we need better physics

12

Including Staging in the Model

Dennis Dees
Project ID # BAT340
Ira Bloom
Project ID # BAT341

C/5

4C

Challenge remains accurately detecting the exact point where Li plating starts

Detecting Li Plating: A Challenge

In situ methods. Question: How close to nucleation can we detect plating?
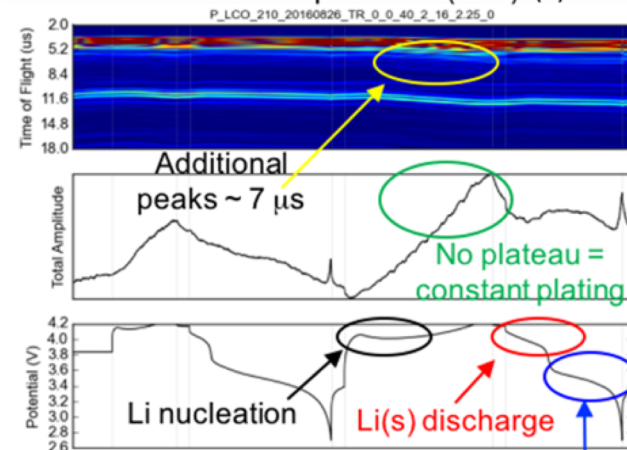
- Electrochemical (coulombic efficiency, capacity fade, electrochemical signatures)
- Acoustic analysis during cycling
- Micro-calorimetry for signature of plating

*Ex-situ* by tear down diagnostics:

- SEM
- XPS.
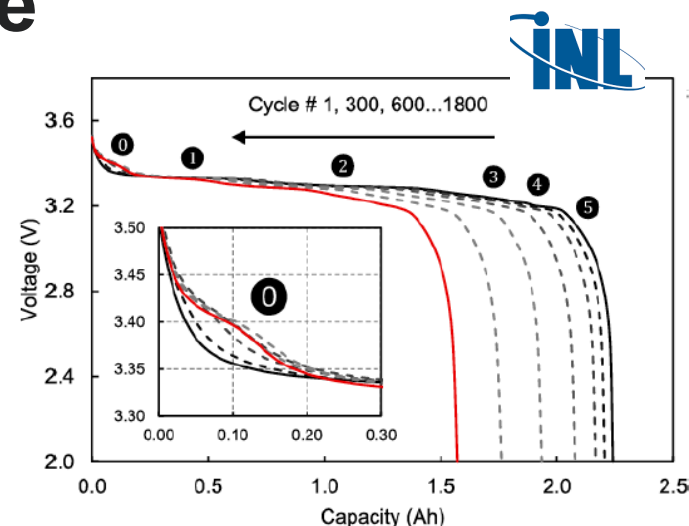
The group is trying a few ideas. But need more

Workshop on Detecting Li plating

Held Dec 6, 2017 at Argonne

- **Experts representing various characterization techniques** including:

  - Electrochemical and related techniques in standard cell configurations

  - Detection techniques in cell configurations consistent with standard cells

  - Model electrode/specialized cell-based techniques

- **Whitepaper released.** Available at:

  https://www.energy.gov/eere/vehicles/downloads/li-plating-detection-whitepaper

- **Broad conclusions**:

  1. Presently-available techniques have the clear potential to detect Li plating

  2. Complementary techniques need to be brought together in order to ensure early detection of plating, along with detection of the location

  3. Need to link electrochemical signatures of plating with direct Li detection.
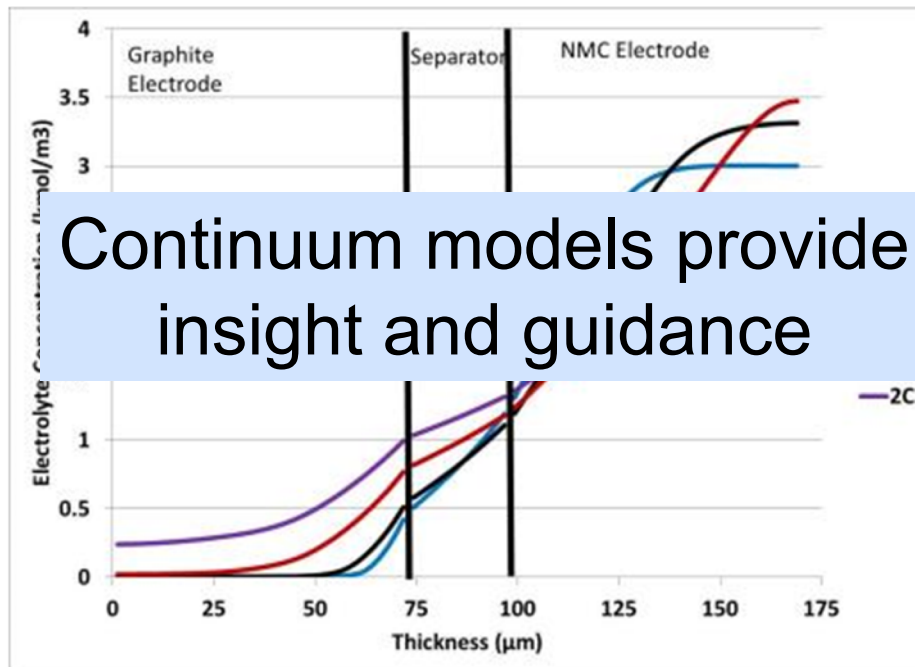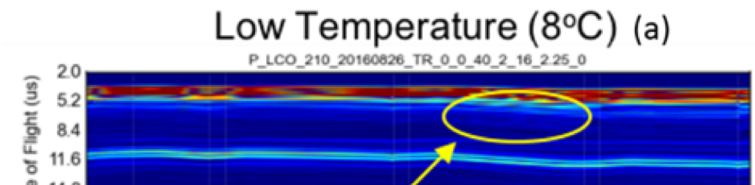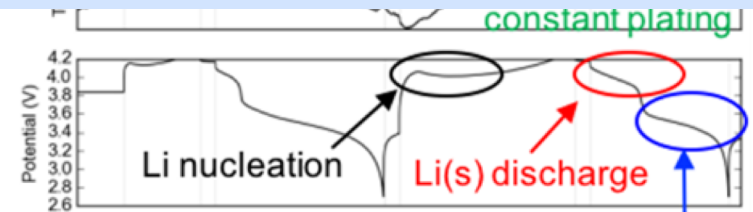
Summary
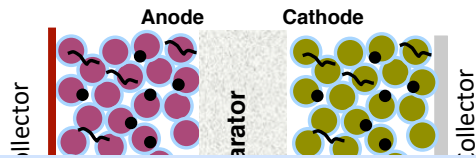
Many reasons for Li plating
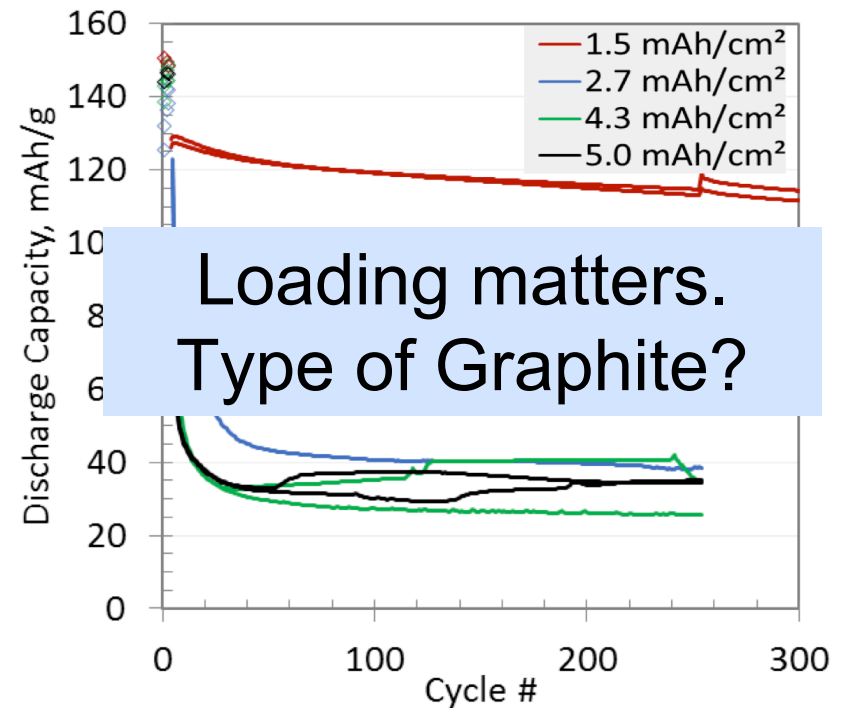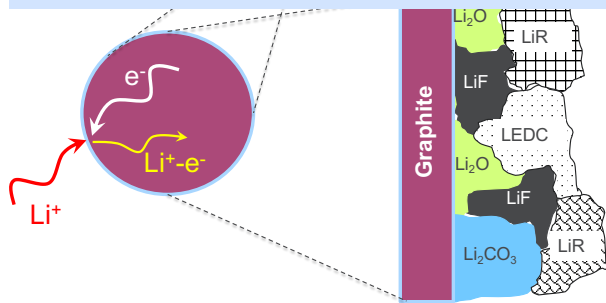
Loading matters. Type of Graphite?

Continuum models provide insight and guidance

Early detection of Li plating critical

Future Tasks

1. What is the effect of thickness, porosity and tortuosity on propensity for Li plating?

2. Can we accurately determine the state at which plating starts to occur?

3. Can we develop a predictive model and use that to design electrodes to minimize propensity for plating?